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Integrated Science Assessment for Particulate Matter

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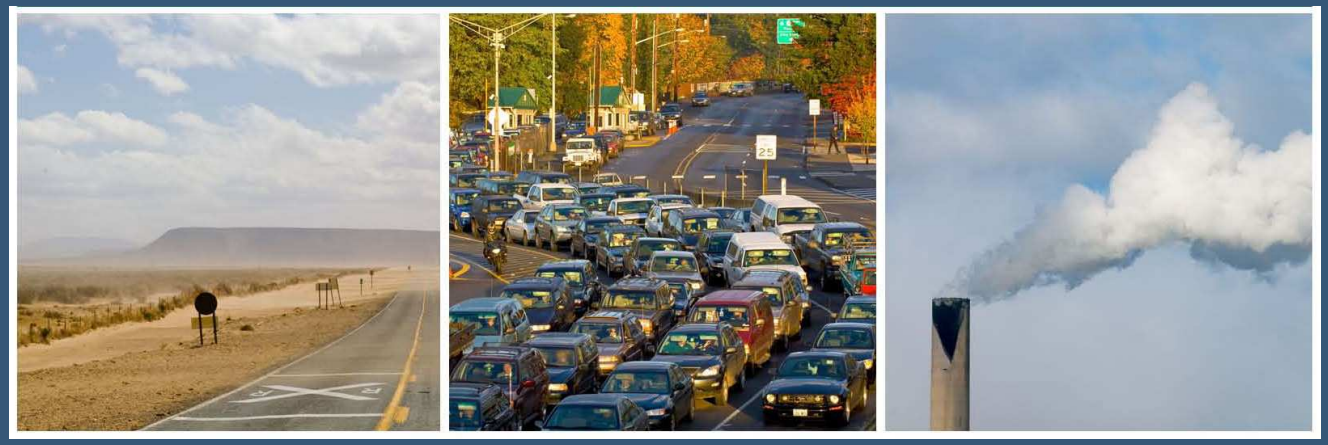
Briefing for California Air Resources Board



Office of Research and Development
National Center for Environmental Assessment, Research Triangle Park, NC

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NAAQS Review Process

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Integrated Science Assessment:
Concise evaluation and synthesis of most policy-relevant studies including epidemiology, human clinical, animal toxicology, human exposure, and atmospheric science

1st Draft *2nd Draft* *Final*

Integrated Review Plan

Identify key policy-relevant issues that will frame the science, risk, and policy assessments

Draft *Final*

Policy Assessment

Staff views on scientific basis for considering adequacy of current standard and alternative policy options, drawing from most policy-relevant science and risk/exposure assessments

1st Draft *2nd Draft* *Final*

Rulemaking Notices:

Agency decision making
Interagency review
Proposed Rule

Public hearings/comment
Agency decision making
Interagency review
Final Rule

Risk/exposure Assessment Reports

Concise quantitative risk/exposure assessments

Plan *1st Draft* *2nd Draft* *Final*

Public workshop
CASAC/public consultation
Early guidance from Agency management

CASAC review and public comment on all draft science, risk/exposure, and policy assessment documents

Opportunity for CASAC and public comment on final assessment documents

Integrated Science Assessment

- Provides scientific basis for NAAQS reviews; formerly known as Air Quality Criteria Document
- Evaluates and integrates evidence from across scientific disciplines – atmospheric sciences, dosimetry, exposure, toxicology, controlled human exposure, epidemiology, ecology, environmental or welfare effects
- Conclusions, causal judgments drawn for health and ecological or environmental effects

→ Focus on health effects of fine particles today

Framework for Causal Determination

Weight of Evidence for Causal Determination

- Causal relationship
- Likely to be a causal relationship
- Suggestive of a causal relationship
- Inadequate to infer a causal relationship
- Not likely to be a causal relationship

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Table 1-3. Weight of evidence for causal determination.

Determination	Health Effects	Ecological and Welfare Effects
CAUSAL RELATIONSHIP	Evidence is sufficient to conclude that there is a causal relationship with relevant pollutant exposures. That is, the pollutant has been shown to result in health effects in studies in which chance, bias, and confounding could be ruled out with reasonable confidence. For example: a) controlled human exposure studies that demonstrate consistent effects; or b) observational studies that cannot be explained by plausible alternatives or are supported by other lines of evidence (e.g., animal studies or mode of action information). Evidence includes replicated and consistent high-quality studies by multiple investigators.	Evidence is sufficient to conclude that there is a causal relationship with relevant pollutant exposures. That is, the pollutant has been shown to result in effects in studies in which chance, bias, and confounding could be ruled out with reasonable confidence. Controlled exposure studies (laboratory or small- to medium-scale field studies) provide the strongest evidence for causality, but the scope of inference may be limited. Generally, determination is based on multiple studies conducted by multiple research groups, and evidence that is considered sufficient to infer a causal relationship is usually obtained from the joint consideration of many lines of evidence that reinforce each other.
LIKELY TO BE A CAUSAL RELATIONSHIP	Evidence is sufficient to conclude that a causal relationship is likely to exist with relevant pollutant exposures, but important uncertainties remain. That is, the pollutant has been shown to result in health effects in studies in which chance and bias can be ruled out with reasonable confidence but potential issues remain. For example: a) observational studies show an association, but copollutant exposures are difficult to address and/or other lines of evidence (controlled human exposure, animal, or mode of action information) are limited or inconsistent; or b) animal toxicological evidence from multiple studies from different laboratories that demonstrate effects, but limited or no human data are available. Evidence generally includes replicated and high-quality studies by multiple investigators.	Evidence is sufficient to conclude that there is a likely causal association with relevant pollutant exposures. That is, an association has been observed between the pollutant and the outcome in studies in which chance, bias and confounding are minimized, but uncertainties remain. For example, field studies show a relationship, but suspected interacting factors cannot be controlled, and other lines of evidence are limited or inconsistent. Generally, determination is based on multiple studies in multiple research groups.
SUGGESTIVE OF A CAUSAL RELATIONSHIP	Evidence is suggestive of a causal relationship with relevant pollutant exposures, but is limited because chance, bias and confounding cannot be ruled out. For example, at least one high-quality epidemiologic study shows an association with a given health outcome but the results of other studies are inconsistent.	Evidence is suggestive of a causal relationship with relevant pollutant exposures, but chance, bias and confounding cannot be ruled out. For example, at least one high-quality study shows an effect, but the results of other studies are inconsistent.
INADEQUATE TO INFER A CAUSAL RELATIONSHIP	Evidence is inadequate to determine that a causal relationship exists with relevant pollutant exposures. The available studies are of insufficient quantity, quality, consistency or statistical power to permit a conclusion regarding the presence or absence of an effect.	The available studies are of insufficient quality, consistency or statistical power to permit a conclusion regarding the presence or absence of an effect.
NOT LIKELY TO BE A CAUSAL RELATIONSHIP	Evidence is suggestive of no causal relationship with relevant pollutant exposures. Several adequate studies, covering the full range of levels of exposure that human beings are known to encounter and considering susceptible populations, are mutually consistent in not showing an effect at any level of exposure.	Several adequate studies, examining relationships with relevant exposures, are consistent in failing to show an effect at any level of exposure.

Previous PM NAAQS Reviews

- 1997: Added standards for fine particles
  - Scientific evidence included many epidemiologic studies using various PM indicators but only 9 studies with fine particle measurements. Little experimental evidence on potential mechanisms for PM-related effects.
  - FR notice: "consistency of the results of the epidemiological studies from a large number of different locations and the coherent nature of the observed effects are suggestive of a likely causal role of ambient PM in contributing to the reported effects."
- 2006:
  - Hundreds of epidemiologic studies available, including numerous studies using $PM_{2.5}$; greatly expanded body of experimental evidence on potential modes of action
  - 2004 AQCD: "A growing body of evidence both from epidemiological and toxicological studies… supports the general conclusion that $PM_{2.5}$ (or one or more $PM_{2.5}$ components), acting alone and/or in combination with gaseous copollutants, are likely causally related to cardiovascular and respiratory mortality and morbidity."

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2009 PM ISA

- Ongoing NAAQS review – Final Rule expected in 2011
  - PM ISA completed in December 2009
- Hundreds of new epidemiologic studies, including many with measured $PM_{2.5}$ and some with $PM_{10-2.5}$ measurements
- Greatly expanded body of evidence from experimental studies on potential modes of action, especially for cardiovascular effects
- Growing body of evidence on potential health effects of PM constituents or sources

Causality Determinations for Short-Term Exposures to PM

Size Fraction	Health Category	Causality Determination
$PM_{2.5}$	Cardiovascular Effects	Causal
	Respiratory Effects	Likely to be Causal
	Central Nervous System	Inadequate
	Mortality	Causal
$PM_{10-2.5}$	Cardiovascular Effects	Suggestive
	Respiratory Effects	Suggestive
	Central Nervous System	Inadequate
	Mortality	Suggestive
Ultrafine PM	Cardiovascular Effects	Suggestive
	Respiratory Effects	Suggestive
	Central Nervous System	Inadequate
	Mortality	Inadequate

Causality Determinations for Long-Term Exposures to PM

Size Fraction	Outcome	Causality Determination
$PM_{2.5}$	Cardiovascular Effects	Causal
	Respiratory Effects	Likely to be Causal
	Reproductive and Developmental	Suggestive
	Cancer	Suggestive
	Mortality	Causal
$PM_{10-2.5}$	Cardiovascular Effects	Inadequate
	Respiratory Effects	Inadequate
	Reproductive and Developmental	Inadequate
	Cancer	Inadequate
	Mortality	Inadequate
Ultrafine PM	All Outcomes	Inadequate

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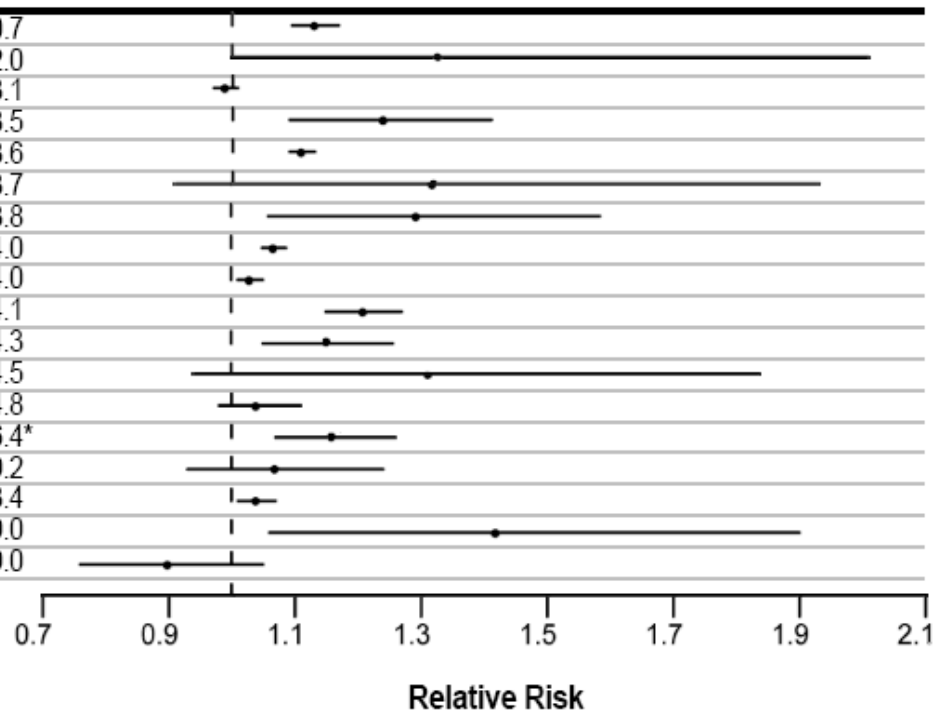
Long-Term Exposures to $PM_{2.5}$

- Causal relationships with mortality and cardiovascular morbidity
  - Consistent associations with mortality, especially cardiovascular mortality
    - Harvard 6 cities, American Cancer Society, Women's Health Initiative cohorts
  - Epidemiologic associations with cardiovascular morbidity in Women's Health Initiative study; less consistent evidence on subclinical markers
  - Biological plausibility and coherence with results of toxicological studies
    - Atherosclerosis development in $ApoE^{-/-}$ mice
    - Coagulation, hypertension and vascular reactivity

Epidemiologic Effect Estimates for Long-Term Exposures to $PM_{2.5}$

Study	Outcome	Mean+
Zeger et al. (2008, 191951)	All-Cause Mortality, Central U.S.	10.7
Kim et al. (2004, 087383)	Bronchitis (Children)	12.0
Zeger et al. (2008, 191951)	All-Cause Mortality, Western U.S.	13.1
Miller et al. (2007, 090130)	CVD Morbidity or Mortality	13.5
Eftim et al. (2008, 099104)	All-Cause Mortality, ACS Sites	13.6
Goss et al. (2004, 055624)	All-Cause Mortality	13.7
McConnell et al. (2003, 049490)	Bronchitis (Children)	13.8
Zeger et al. (2008, 191951)	All-Cause Mortality, Eastern U.S.	14.0
Krewski et al. (2009, 191193)	All-Cause Mortality	14.0
Eftim et al. (2008, 099104)	All-Cause Mortality, Harv 6-Cities	14.1
Lipfert et al. (2006, 088756)	All-Cause Mortality	14.3
Dockery et al. (1996, 046219)	Bronchitis (Children)	14.5
Woodruff et al. (2008, 098386)	Infant Mortality (Respiratory)	14.8
Laden et al. (2006, 087605)	All-Cause Mortality	16.4*
Woodruff et al. (2008, 098386)	Infant Mortality (Respiratory)	19.2
Enstrom (2005, 087356)	All-Cause Mortality	23.4
Chen et al. (2005, 087942)	CHD Mortality, Females	29.0
	CHD Mortality, Males	29.0



* Mean estimated from data in study
\+ $\mu g/m^3$

Figure 2-2. **Summary of effect estimates (per 10 $\mu g/m^3$) by increasing concentration from U.S. studies examining the association between long-term exposure to $PM_{2.5}$ and cardiovascular and respiratory effects, and mortality.**

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Short-Term Exposures to $PM_{2.5}$

- Causal relationships with mortality and cardiovascular morbidity
  - Consistent associations in epidemiologic studies of cardiovascular hospitalization or ED visits, especially ischemic heart disease and congestive heart failure. Epidemiologic studies show associations with cardiovascular mortality in multicity studies. New studies show some evidence of regional heterogeneity.
  - Myocardial ischemia observed across all disciplines
  - Controlled human exposure studies report altered vasomotor function with diesel exhaust exposure or CAPs with ozone; uncertainty in attribution of effects to particles.
  - Animal toxicological studies show evidence of altered vessel tone and microvascular reactivity, providing coherence and biological plausibility for vasomotor effects.

Mode of Action: Cardiovascular Effects

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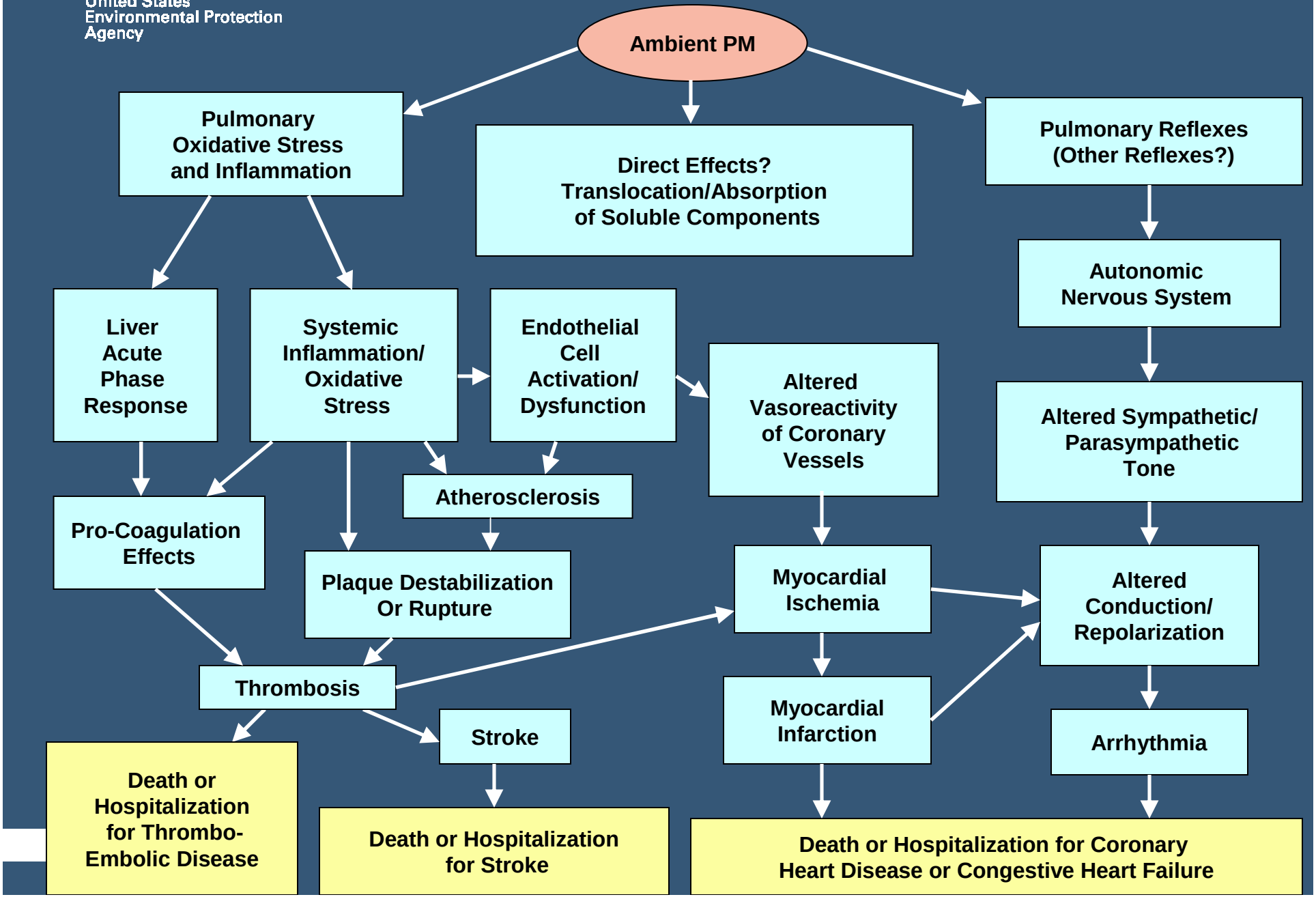
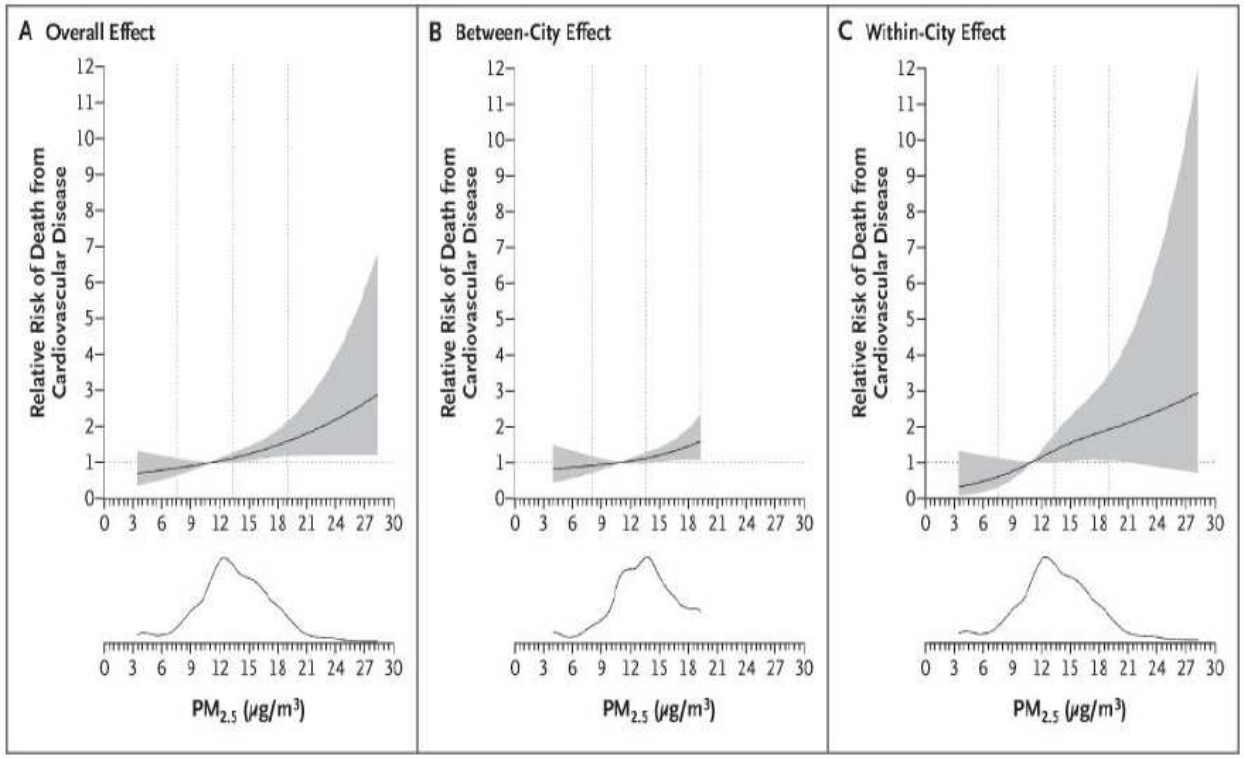


Fine Particle Constituents

- 2009 PM ISA evaluated studies on health effects for ambient PM sources or constituents, including source apportionment studies
- Overall conclusion:
  - Many components linked with various health outcomes
  - Evidence not sufficient to differentiate effects of constituents or sources on specific health outcomes
- Examples of some potential linkages:
  - Cardiovascular effects associations with $PM_{2.5}$ from motor vehicle emissions, wood or biomass burning, and PM (both $PM_{2.5}$ and $PM_{10\text{-}2.5}$) from crustal or road dust sources
  - Mortality associations with PM from combustion sources (coal, oil) and secondary sulfate/long-range transport PM source factor

Concentration-Response Relationships

Most studies indicate that a log-linear nonthreshold model best fits PM-health outcome relationships



Source: Miller et al. (2007, 090130)

Figure 7-8. Plots of the relative risk of death from cardiovascular disease from the Women's Health Initiative study displaying the between-city and within-city contributions to the overall association between $PM_{2.5}$ and cardiovascular mortality windows of exposure-effects.

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Conclusions

- Tremendous body of research into health effects of PM
- Increasing coherence and consistency in scientific evidence on the health effects of PM with each NAAQS review; greatest body of evidence on fine particles
- 2009 PM ISA concludes “causal relationships” for both short-term and long-term exposure to $PM_{2.5}$ with mortality and cardiovascular morbidity.
- Growing body of evidence on health effects of fine particle constituents or sources; not sufficient to differentiate effects on specific health outcomes
- Health studies do not identify a threshold for effects

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Supplemental Material

History of the PM NAAQS

Final Rule	Indicator	Ave. Time	Level	Form
1971	TSP - Total Suspended Particles (≤ 25-45 µm)	24-hour	260 µg/m^3 (primary) 150 µg/m^3 (secondary)	Not to be exceeded more than once per year
		Annual	75 µg/m^3 (primary)	Annual average
1987	PM_{10}	24-hour	150 µg/m^3	Not to be exceeded more than once per year
		Annual	50 µg/m^3	Annual average
1997	$PM_{2.5}$	24-hour	65 µg/m^3	98th percentile
		Annual	15 µg/m^3	Annual arithmetic mean, ave. over 3 years
	PM_{10}	24-hour	150 µg/m^3	Initially promulgated 99th percentile form; when 1997 standards were vacated, form of 1987 standards remained in place (not to be exceeded more than once per year on ave. over a three year period)
		Annual	50 µg/m^3	Annual arithmetic mean, ave. over 3 years
2006	**$PM_{2.5}$**	**24-hour**	**35 µg/m^3**	**98th percentile, ave. over 3 years**
		Annual	**15 µg/m^3**	**Annual arithmetic mean, ave. over 3 years**
	PM_{10}	**24-hour**	**150 µg/m^3**	**Not to be exceeded more than once per year on ave. over a 3 year period**

NAAQS Background

- Clean Air Act (CAA) requires EPA to review "air quality criteria" and NAAQS every 5 years for "criteria" pollutants (ozone, PM, CO, SO_2, NO_2, lead) (CAA §109)
  - Air quality criteria are to "accurately reflect latest scientific knowledge"
  - Primary (health-based) and secondary (welfare-based) NAAQS based on the air quality criteria
- Requires the Administrator to appoint an independent scientific committee to review the air quality criteria and NAAQS and to "recommend to the Administrator any new . . . standards and revisions to existing [air quality] criteria and standards as may be appropriate" (CAA §109)
  - Independent review function performed by Clean Air Scientific Advisory Committee (CASAC)

Current NAAQS Review Schedules

NO_2

SO_2

Ozone

CO

PM

NO_X/SO_X